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Our reference
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Device for permitting rail vehicles to travel in an optimum way with respect to energy in local transport systems

The invention relates to a device for permitting rail vehicles to travel in an optimum way with respect to energy in local transport systems in which the vehicles are to reach each following stop as punctually as possible while complying with the timetable and are to leave said stops again at different times, each vehicle being equipped with vehicle equipment, transmitter and receiver devices, measuring devices for determining location and speed, and being able to exchange data telegrams with a fixed operations center and a fixed station computer.

Such devices are known, for example, from DE-PS 15 30 456. The intention is that municipal rail vehicles will travel more economically by virtue of the fact that when they leave a stop they will firstly travel with maximum acceleration until they have reached a precalculated value of a peak speed (switch-off speed) which is not to be exceeded. Then, the rail vehicle continues to travel without further acceleration in a coasting mode which is terminated by a braking operation just before it reaches the next stop. In each case the shortest traveling time between two stops is taken into account in the determination of the permitted peak speed. It is possible, owing to the uncertainty in the drawing up of the timetable and/or in order to take into account different loads coupled to the vehicle, to calculate a traveling time supplement as a reserve. This traveling time reserve, which is small with automatic train control, is used for the longest possible coasting mode in normal operation, that is to say when there are no delays. As a result, the peak speed is not as high and a large

amount of energy can be saved because the energy consumption increases approximately with the square of the peak speed.

In the known devices, the value of the peak speed (switch-off speed) is also determined as a function of the time period between the arrival time of a train at the respective stop according to the timetable and the departure time. If the momentary speed has reached the switch-off speed, the current is switched off and the vehicle coasts in an uncontrolled way until the braking phase is reached. This is a control system. The use of such a control system requires the driver of the locomotive to intervene when conditions are unfavorable (for example there is a head wind) so that the vehicle does not come to a standstill before the destination station. This possible way of implementing travel which is optimum with respect to energy is not very suitable for a fully automatic, driverless train control system because the following secondary conditions, which may lead to infringement of the safety requirements, cannot be taken into account. These are:

a) the constant secondary conditions
   1- the route-dependent gradients (negative gradient, positive gradient)
   2- the route-dependent speed restrictions (locations of speed restrictions)

b) the variable secondary conditions
   1- the speed-dependent resistance to movement (for example head wind)
   2- the fixed or moveable hazardous points.

For an automatic local transport system it is therefore necessary to increase further the implementation of the known principle of traveling in an optimum way with respect to energy.

The invention is based on the object of improving a device of the type mentioned at the beginning in such a way that the vehicles in local transport systems travel in an optimum way with respect to energy while taking into account the aforementioned secondary conditions.

The object is achieved according to the invention in that, on the one hand, the vehicle equipment continuously receives the location of fixed or moveable hazardous points from the operations center and, on the other hand, it intermittently receives at each stop, from the station computer, the speed profile (v profile) and a state square with control variables which are optimum with respect to energy for the route section as far as the next stop, and in that the vehicle equipment performs the control functions for travel in an optimum way with respect to energy, and additionally carries out technical safety functions, while taking into account in particular compliance with the speed profile, the safe maintenance of the distance from the hazardous points, and the changing route resistances and travel resistances.

By means of this device it is advantageously possible for the first time to enable local transport rail vehicles to travel safely fully-automatically in compliance with the timetable and in an optimum way with respect to energy.

Advantageous developments are characterized in the subclaims.

Exemplary embodiments of the invention are illustrated in the drawing and will be explained below.

In the drawing:

Figure 1 shows an overview in block form for devices on the route and on a vehicle,

Figure 2 shows a breakdown overview of a decentralized local traffic automation system,

Figure 3 shows a state square for an optimization method according to Bellman,

Figure 4 shows an exemplary calculation according to the optimization principle based on the state square according to figure 3,

Figure 5 shows the block circuit diagram of a central computer for determining control variables which are optimum with respect to energy,

Figure 6 shows details of a vehicle control system, and

Figure 7 shows the block circuit diagram of a vehicle protection device.

The block circuit diagram according to figure 1 illustrates a course structure of the vehicle equipment FT in conjunction with route-mounted devices. The latter transmit intermittent information $\underline{u}$ (v, s, t) and the v profile to the stops and continuously transmit the location s_H of any respective hazardous points. The functions are separated into vehicle control FG1 and vehicle protection FG2. In this way, it is also possible in each case to make a clear division with respect to the software and the hardware. The advantage is that the particular expenditure on the detection of faults which can lead to hazards in the operation of rail vehicles only needs to be used for protection functions.

The vehicle protection system FG2 monitors the vehicle control system FG1 and, by means of a reliable switch S1, either causes the protection commands USI or the control commands UST to be switched through to the input of the actuator elements SMR via a D/A converter WR1. The protection commands USI then pass to the actuator elements SMR if the safety requirements are no longer fulfilled or, owing to a fault in the local transport system and a long delay, optimum travel with

respect to energy is not possible. The safety-related devices are represented as blocks with a double outline.

When the distances between stops in a municipal area are small, the control variables $\underline{u}$ (v, s, t) which are optimum with respect to energy between two stops are transmitted to the vehicle equipment when the vehicle arrives at each stop. For this purpose, reliable receiving and measuring devices are provided. Before the departure, the control variables are therefore present in the vehicle equipment as a function of the speed, the location and the travel time. The control variables do not have any responsibility for safety. As soon as the signal Travel FS1 is triggered either by the center or a device on board the vehicle, the vehicle is controlled in an optimum way with respect to energy as far as the next stop by the microcomputer MR by means of the control variables which are optimum with respect to energy and the stored control algorithms which are optimum with respect to energy. The vehicle control which is optimum with respect to energy takes into account the route-dependent speed restriction (locations of speed restrictions), the gradients (negative gradient, positive gradient) and compensates the influences of the speed-dependent movement resistances (for example head wind) and the measuring errors (speed, location). This is therefore control which is optimum with respect to energy. Later, a device is described which is used to acquire the control variables which are optimum with respect to energy in the center. If a delay which has occurred is so long that the vehicle can no longer travel in an optimum way with respect to energy, a command FS2 is transmitted to the vehicle protection system FG2 so that the vehicle is controlled in accordance with the speed profile (route-dependent speed restrictions).

The vehicle protection system FG2 monitors to ensure that each vehicle maintains a sufficiently large distance from a vehicle travelling ahead or from a fixed hazardous point and also to ensure that the momentary speed v_{act} does not exceed the maximum speed for the route. The switch-over strategy UE continuously monitors these two safety requirements and as soon as one of them is no longer fulfilled, it switches off the influence of the vehicle control system FG1 on the vehicle using the switch S1, and one of the safety functions, the maintenance of distance AG or traveling in accordance with the speed profile GL assumes the control of the vehicle from them on. The two safety functions of the maintenance of distance AG and traveling according to the speed profile GL monitor one another.

Assuming that the vehicle is traveling according to the speed profile GL and suddenly an unforeseen obstacle arises, for example a vehicle traveling ahead suddenly stops due to derailment. At this moment, the switch-over strategy UE must switch off the travel according to the speed profile GL and switch on the maintenance of distance AG. The latter influences the vehicle in such a way that the vehicle has reduced its speed to zero precisely at the location of the obstacle.

Before the structure of the vehicle equipment FT according to figure 1 is explained further, the model of the decentralized local-transport information system according to figure 2, in which the vehicle equipment FT (figure 1) is operated, will be described in more detail. The model has a modular structure and is divided into a deployment center DZ, an operations center OZ, a station computer STR1 to STR3 and vehicle equipment FT. The control variables $\underline{u}$ (v, s, t) which are optimum with respect to energy are transmitted to the station and the route-dependent speed restrictions

(v profile) as far as the next station are transmitted to the vehicle equipment FT. When the vehicle has left the station, the location of the hazardous point lying ahead is transmitted continuously to the vehicle equipment FT so that the vehicle can be controlled safely and punctually as far as the next stop in a way which is optimum with respect to energy. While the vehicle is traveling, all the speed restrictions, the gradients and the hazardous points are taken into account and all the disruptive influences, for example head wind, are compensated. Each vehicle reports its departure time t_{dep} to the station computer STR1, STR2 and STR3, said departure time t_{dep} passing to the operations center OZ via the respective station computer. On the route, the location of the vehicle is continuously measured and also transmitted to the operations center OZ. This information is used to make the precalculation of the timing in order to neutralize conflicts even before they occur and avoid congestion. The stationary components of the system can exchange data via the links which are present.

Firstly, the optimization function will be formulated: a permissible control $\underline{u}$ (v, s, t) is sought from a control range in such a way that the vehicle is transferred from the source station to the destination station in such a punctual way that the consumed energy assumes its smallest value while the control variable restrictions, location restrictions and speed restrictions are complied with. The control range lies here in the limits which are determined by the maximum specific traction force or braking force. The range which is permitted for the speed and the location is determined by the route-dependent speed restrictions and thus by virtue of the fact that the vehicle must not travel back or beyond the destination.

In order to perform the optimization function which is set, the "Bellman optimization method" is selected.

This optimization method was referred to by Bellman as "dynamic programming". Here, the stated problem is embedded in a class of similar functions which all lead jointly to the solution as indicated in accordance with the representation in figure 3. The edges of a state square ZQ correspond to the longest travel time t_f, the maximum speed VM for the route and the distance between stops HAD between the source station and the destination station. The travel time given departure in accordance with the timetable is designated by t_p, and by t_v if there is a delayed departure. Ranges of early or delayed departure times have the reference symbol X or Y, respectively. The optimum trajectory which is described by the vehicle during travel in an optimum way with respect to energy lies in this state square ZQ. The theoretically infinitely large number of possible time values, location values and speed values are discretized in order to keep their number finite. In this way, a finely meshed grid is produced in the state square ZQ. The calculation of all the values then only needs to be restricted to the grid points. The procedure consists in searching for all the possible linking trajectories which give the consumed energy a minimum value. The time interval T corresponds to the sampling time during the acquisition of measured values. This method has the advantage that the entire range within the state square ZQ is searched, as a result of which all difficult mathematical investigations relating to sufficient conditions, unique definition and existence are dispensed with. Restrictions on the speed and location have only a positive result in which the region to be searched, and thus the expenditure, is reduced.

Because the solution of the optimization objective which is set here permits variation of the departure time, but always aims at punctual arrival, the strategy of backward recursion is selected in the application of Bellman's method. For each of the grid points (v, s) of

the state square ZQ at the level k = N-1, that trajectory which leads to the destination station is searched for. The control variable and the consumed energy of each trajectory are calculated and stored at the corresponding grid point. k = N-2 is inserted and the control variable of the trajectory which is optimum with respect to energy, and which leads via the level k = N-1 to the destination station is searched for all the grid points at this level: in the process, the optimization principle of Bellman is applied. Therefore, by working backwards, the level k = 0 is finally reached and thus in particular also the source station. The control variable which is optimum with respect to energy is always stored at the corresponding grid point.

Figure 4 illustrates an example of the state square ZQ for a type of vehicle and for a specific route section. Before the arrival of the vehicle at the stop, the state square must already be present in the memory of the station computer. After the arrival of the vehicle at the stop, the state square ZQ is transmitted to the vehicle equipment. This state square, which includes the control variables which are optimum with respect to energy, is further processed by the vehicle controller FG1 in figure 1. An exemplary calculation is shown with four levels, the distance from a stop being 1000 m and the travel time being 100 sec. The control variables which are optimum with respect to energy are noted on the right below the respective grid points. During a time interval (difference between two adjacent levels), the control variable is composed of two discrete values

u_1 for $0 \leq t \quad T/2$

and

u_2 for $T/2 \leq t<T$

If there is no trajectory at all on which the vehicle can travel to the destination station from the grid point in question owing to the location restrictions, speed restrictions and control variable restrictions, the value ∞ is accordingly assigned to the control variable, i.e. it is forbidden to travel via this grid point.

In the deployment center DZ in figure 2, there is a central processing unit ZR (figure 1) which creates the state square ZQ (figure 1, 3) with the control variables which are optimum with respect to energy, in accordance with the method of operation described.

Figure 5 illustrates this device ZR with the state square ZQ. Under vehicle data, the longest travel time t_f, the distance between stops and the route data are used as the input data EG for the computer ZR. The route data is composed of two of the four secondary conditions to be taken into account: the route-dependent gradients (negative gradient, positive grating) and the route-dependent speed restrictions. Such a state square is created for each type of vehicle and for each route section (distance between two stops).

Figure 6 shows the structure of the vehicle control system FG1 (figure 1). The device is composed of the state square ZQ (control variables which are optimum with respect to energy), an optimum-energy-consumption controller EOR and a mathematical vehicle model MFM. As soon as the signal Travel FS1 is triggered either by the center or a device on board the vehicle, this time is designated as the departure time and is adapted to the level number k, cf. figure 4 in this respect. Because the vehicle is located at the source station, the actual speed v_{act} and the actual location s_{act} have the value zero. From the state square ZQ, the control variable u which is optimum with respect to energy

results from the three data items (v, s, k). In accordance with the control variable which is adopted, the travel command UST is passed on to the switch S1 (figure 1). At the same time, this travel command is input into the mathematical vehicle model MFM. The mathematical vehicle model also travels in parallel with the real vehicle and is used for interpolating the control variable which is optimum with respect to energy if the vehicle has left the optimum trajectory as a result of the disruptive influences, or the actual speed and the actual location do not correspond to a grid point in the state square ZQ.

In one case, the control variable u which is optimum with respect to energy is obtained from the state square. If this control variable has a finite value, the travel command UST is accordingly fed to the input of the switch S1. However, if this value is infinite, a disruption has affected the vehicle during the last time interval, as a result of which the vehicle has reached the prohibited state. During the creation of the state square ZQ, prohibitions were of course placed on the vehicle by means of the grid points with the value ∞. The optimum-energy-consumption controller EOR does not test whether this travel prohibition has been caused by the location restrictions or speed restrictions but rather it determines approximately the control variable which is optimum with respect to energy. A control algorithm has been developed for this purpose. This control algorithm is implemented in EOR, figure 6, and requires the actual location and the actual speed of the vehicle model. These two values are supplied by the mathematical vehicle model MFM. According to this determination, the control command UST is correspondingly supplied to the switch S1.

In the other case it is assumed that the actual speed and the actual location of the vehicle deviate from the coordinates of a grid point in the state square ZQ.

Then, an interpolation is necessary in order to approximately determine the control variable. The required control algorithm has also been implemented in the controller EOR, and the mathematical vehicle model MFM is also included. The manipulated variable is then passed on to the switch S1.

Using the actual location and the actual speed of the vehicle model MFM, the control variable u which is optimum with respect to energy is read out of the state square ZQ and inserted into the mathematical vehicle model MFM. This always hits a grid point because the state square ZQ has been created with this vehicle model MFM, and the model cannot experience any fault during travel. After each time interval, the above steps are run through until the vehicle has reached the destination station.

The property of this vehicle equipment and of the device for creating this state square ZQ that the control variables which are optimum with respect to energy are determined by the functions u (v, s, t) after each sampling time as a function of the vehicle state which is present at that particular time (actual speed and actual location), is favorable with respect to control technology because it provides the possibility of compensating disruptive influences on the vehicle, for example a head wind. Here, all the influences which impede the vehicle from traveling in an optimum way with respect to energy, and as a result of which the vehicle travels more quickly or more slowly than it actually should, are classified as faults. Irrespective of whether or not the vehicle hits a grid point as a result of the disruptive influences, a control variable which is optimum in terms of energy is always obtained from the state square ZQ or determined with the interpolation. The vehicle always approximately follows one of the trajectories which are

optimum in terms of energy and which lead punctually to the destination station.

During the creation of the state square ZQ, backward recursion was selected in the applied Bellman optimization method. The advantage is that, in addition to the sought trajectory which is optimum in terms of energy, from a predefined source station to the destination station, the backward recursion additionally supplies trajectories which are optimum in terms of energy from other points in the permitted range to the destination station. This is a consequence of the embedding of the optimization function which is set into various classes of similar functions. If these faults influence the travel characteristics of the vehicle in such a way that, for example, the actual speed is equal to the speed restriction, the vehicle protection system switches on and assumes the control of the vehicle from then on.

The property that the control variables which are optimum in terms of energy have come about as a function of the actual location and the actual speed also has other advantages which are apparent from figure 4.

The time axis t is the set of all departure times from the source station. In order to create the state square, the longest travel time is selected, and at the departure from the source station the associated control variable is obtained in accordance with the departure time on the time axis, and the vehicle is thus controlled as far as the destination station in accordance with the explained strategy. In the example according to figure 4, the vehicle can still travel as far as the destination station in an optimum way with respect to energy at the level k = 0 or 1, but can no longer do so at the level k = 2 or 3. If, for whatever reason, the vehicle only departs at the level k = 2 or

3, the optimum-energy-consumption controller transmits the signal FS2 (figures 1, 6) to the vehicle protection system FG2 which controls the vehicle as far as the destination station.
The time axis and location axis together form a plane which represents the set of all grid points with the speed zero. If, for whatever reason, a vehicle has come to a standstill on this plane, it can still be controlled as far as the destination station in an optimum way with respect to energy. A precondition is that an infinite control variable is previously noted at the corresponding stops in the state square ZQ, and the vehicle equipment and the drive elements have not become faulty. According to figure 4, at least one departure which is optimum in terms of energy from the time-location plane is possible at all the levels.

The block circuit diagram according to figure 7 illustrates the structure of the device for vehicle protection FG2, figure 1. It is of modular design and is divided into a switch-over strategy UE, maintenance of distance AG, braking distance computer BR, switch S2, speed control VR and limiting speed computer VGR.

Basically, the following safety requirements must be fulfilled during the operation of the rail vehicle:

a) Safety requirement to protect against rear-end collisions

$$s_H = s_{act} \geq a$$

Actual distance ≥ braking distance a,

here, s_H is the location of the obstacle, that is to say the location of the fixed or moveable hazardous point.

b) Safety requirement to protect against a maximum speed for the route being exceeded

$$v_{act} \leq v_G$$

Actual speed ≤ maximum speed for the route.

The vehicle protection system FG2 monitors the vehicle control system FG1 in accordance with each sampling time in the following way:

In order to travel in accordance with the speed profile (v profile) (figures 1, 7), the limiting speed computer VGR determines from said speed profile the limiting speed which must not be exceeded. The switch-over strategy UE compares the limiting speed v_G with the actual speed v_{act} which is supplied by the measuring elements. As long as v_{act} is $\leq v_G$, the travel commands UST of the vehicle control system FG1 pass to the actuator elements. However, if the condition is no longer fulfilled, the travel commands UST are no longer let through by the switch S1 in figure 1, i.e. the signal FS3 activates S1, and the travel commands USI of the vehicle protection system FG2 then pass to the actuator elements. The speed controller VR forms the travel commands USI from v_{act} and v_G. The actual speed is controlled by the speed controller VR to the determined limiting speed with a narrow tolerance limit independently of the gradient and the absolute value of the vehicle.

In order to maintain distance, the braking distance computer determines the braking distance a from the actual speed. The switch-over strategy UE forms the actual distance (s_H-s_{act}) between a vehicle which is traveling ahead and the following vehicle. As long as the actual distance is greater than the braking distance a, the travel commands UST of the vehicle control system FG1 pass to the actuator elements.

However, if the safety requirement to protect against rear-end collisions is no longer fulfilled, the travel commands UST are no longer let through and the travel commands (protection commands) USI of the vehicle protection system FG2 pass to the actuator elements. At this time, the distance controller AG is switched on. It forms a setpoint value v_{SR} for the speed controller VR from the actual distance s_H and the braking distance a.

At the distance controller AG, the concept of two-loop cascade control is applied. The speed control forms the inner control loop here and the distance control the outer control loop. The setpoint value for the speed controller is v_G for travel according to the speed profile and v_{SR} for the maintenance of distance. The signal FS4 conducts or blocks one of these values in each case, using the switch S2 for the input of the speed control VR. The distance controller AG influences the vehicle in such a way that when there is a stationary obstacle the vehicle has to be brought to a standstill in order to reach the obstacle.

The two safety devices for travelling in accordance with the speed profile and the maintenance of distance monitor one another. Assuming that the vehicle travels with the distance controller AG and the actual speed exceeds the limiting speed, the switch-over strategy UE switches the distance controller AG off by means of the switch S2, and the speed controller VR receives the limiting speed V_G as a setpoint value, provided that the safety distance is still ensured at that moment.

Conversely, if operations are being carried out in accordance with the speed profile, the switch-over strategy UE monitors the distance between the vehicle and the vehicle traveling ahead.

The vehicle protection system FG2 is coupled to the vehicle control system FG1 by means of the signal FS2 (figure 1, 7). The vehicle control system FG1 transmits the signal FS2 to the vehicle protection system FG2 if the delay is so long that optimum travel with respect to energy is not possible. The vehicle is then controlled with the speed controller VR which receives the limiting speed v_G as a setpoint value.

Patent claims

1. A device for permitting rail vehicles to travel in an optimum way with respect to energy in local transport systems in which the vehicles are to reach each following stop as punctually as possible while complying with the timetable and are to leave said stops again at different times, each vehicle being equipped with vehicle equipment, transmitter and receiver devices, measuring devices for determining location and speed, and being able to exchange data telegrams with a fixed operations center and a fixed station computer, characterized in that, on the one hand, the vehicle equipment (FT) continuously receives the location (S_H) of fixed or moveable hazardous points from the operations center (OZ) and, on the other hand, it intermittently receives at each stop, from the station computer (STR), the speed profile (v profile) and a state square ($\underline{ZQ}$) with control variables which are optimum with respect to energy for the route section as far as the next stop, and in that the vehicle equipment (FT) performs the control functions for travel in an optimum way with respect to energy, and additionally carries out technical safety functions, while taking into account in particular compliance with the speed profile, the safe maintenance of the distance from the hazardous points, and the changing route resistances and travel resistances.

2. The device as claimed in claim 1, characterized in that there is a central processing unit (ZR) in the fixed operations center which creates a state square ($\underline{ZQ}$) for each type of vehicle and for each route section between two stops, the edges of which state square ($\underline{ZQ}$) correspond to the longest travel time (t_f), the distance between stops and the maximum speed for the route, in that a control variable which is optimum with respect to energy and which is determined according to the Bellman optimization method taking

into account route-dependent speed restrictions (speed profile), gradients (negative gradient, positive gradients) and vehicle data, is noted at each point in the state square (ZQ).

3. The device as claimed in claim 2, characterized in that the control variables u (v, s, t) which are optimum in terms of energy are determined as a function of the speed, the route and the travel time.

4. The device as claimed in claim 1, characterized in that the functions of the vehicle equipment (FT) are divided into vehicle protection (FG2) and vehicle control (FG1).

5. The device as claimed in claims 1 to 4, characterized in that, after the arrival of the vehicle at the stop, the state square (ZQ) with the control variables which are optimum in terms of energy is transmitted to the vehicle equipment, the vehicle being controlled in an optimum way with respect to energy as far as the next stop if the signal Travel (FS1) is triggered by the operations center or on board the vehicle and if the travel time is no longer sufficient to travel in an optimum way with respect to energy, another signal (FS2) is transmitted to the vehicle protection system which controls the vehicle as far as the next stop.

6. The device as claimed in claims 4 and 5, characterized in that the vehicle control system contains an optimum-energy-consumption controller (EOR), receives the measured values (speed, travel) from the measuring devices after each sampling time interval (T) and thus obtains the corresponding control variable which is optimum with respect to energy from the state square (ZQ), which is transmitted as a travel command to the drive elements if the measured values

correspond to the coordinates of a grid point in the state square (ZQ).

7. The device as claimed in claim 6, characterized in that the controller (EOR) which is optimum with respect to energy contains a module which approximately determines the control variable which is optimum with respect to energy using the mathematical vehicle model (MFM) if the measured values do not correspond to the coordinates of a grid point in the state square (ZQ).

8. The device as claimed in claim 4, characterized in that the vehicle control system contains a mathematical vehicle model (MFM) which always travels in parallel with the real vehicle and is used to correct the control variables which are optimum with respect to energy if the vehicle has left the trajectory which is optimum with respect to energy as a result of disruptive influences (for example headwind).

9. The device as claimed in claims 2 and 3, characterized in that the control variable which is optimum with respect to energy is obtained from the state square (ZQ) as a function of measured values (speed, location) after each sampling time or is determined by means of interpolation.

10. The device according to claims 2, 3 and 9, characterized in that the edge of the state square (ZQ) which corresponds to the time axis constitutes the set of all departure times from the source station, in that, in order to create the state square (ZQ), the longest travel time is selected and at the departure from the source station the optimum-energy-consumption controller (EOR) obtains the associated control variable which is optimum with respect to energy on the time axis from the state square (ZQ) in accordance with the departure time.

11. The device as claimed in one of claims 2, 3 and 9, characterized in that the edges of the state square (ZQ) which correspond to the time axis and location axis constitute the set of all the points of the state square (ZQ) with the speed zero.

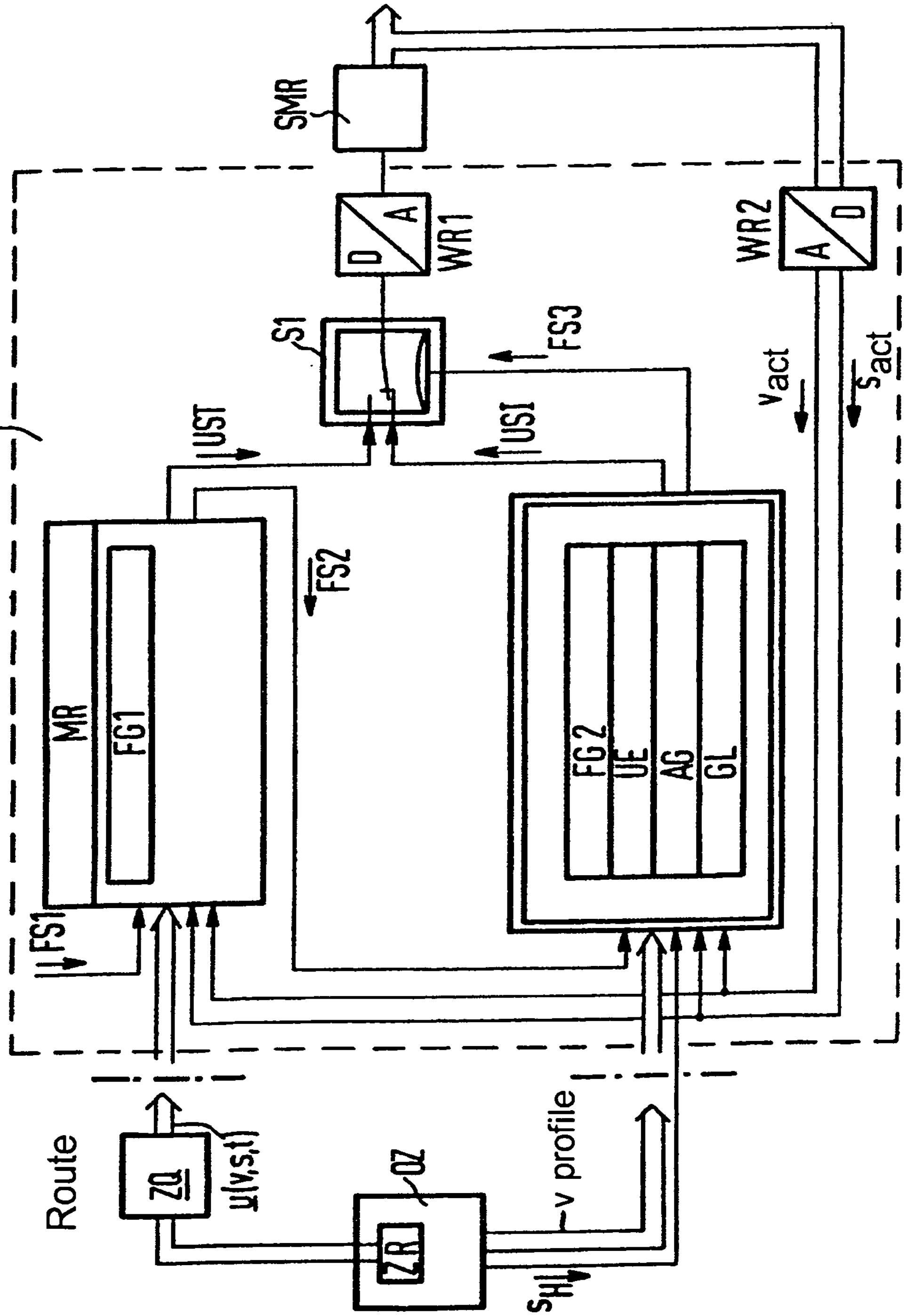
12. The device as claimed in claim 4, characterized in that after each sampling time the switch-over strategy (UE) compares the limiting speed which is determined from the route-dependent speed restrictions (VGR) with the momentary speed which is acquired from the acquisition of the measured values, in that when there is identity between the momentary and the limiting speed the influence of the vehicle control system (FG1) on the vehicle is de-activated (switch S1) and the speed controller (VR) assumes the control of the vehicle from then on.

13. The device as claimed in claim 4, characterized in that after each sampling time the switch-over strategy (UE) compares the difference between the measured value (location) and the location of an obstacle, which is continuously transmitted to the vehicle equipment (FT), with the braking distance, and in that when there is identity between the two variables the influence of the vehicle control system (FG1) on the vehicle is de-activated (switch S1) and the distance controller (AG) assumes the control of the vehicle from then on.

14. The device as claimed in one of claims 12 and 13, characterized in that the distance controller (AG) and the speed controller (VR) monitor one another so that if the distance controller (AG) controls the vehicle and the limiting speed is exceeded, the switch-over strategy (UE) switches off the distance controller (AG) and the speed controller (VR) assumes the control of the vehicle (switch S2) from then on, and vice versa if the speed controller (VR) controls the vehicle and the braking distance is undershot, the switch-over strategy

(UE) switches off the speed controller (VR) and the distance controller (AG) assumes the control of the vehicle from then on.

FIG 1



FT
MR
FG1
FG2
UE
AG
GL
S1
SMR
D
A
WR1
A
D
WR2
UST
USI
FS1
FS2
FS3
v_{act}
s_{act}
Route
ZQ
y(v,s,t)
QZ
ZR
v profile
s_H

FIG 2

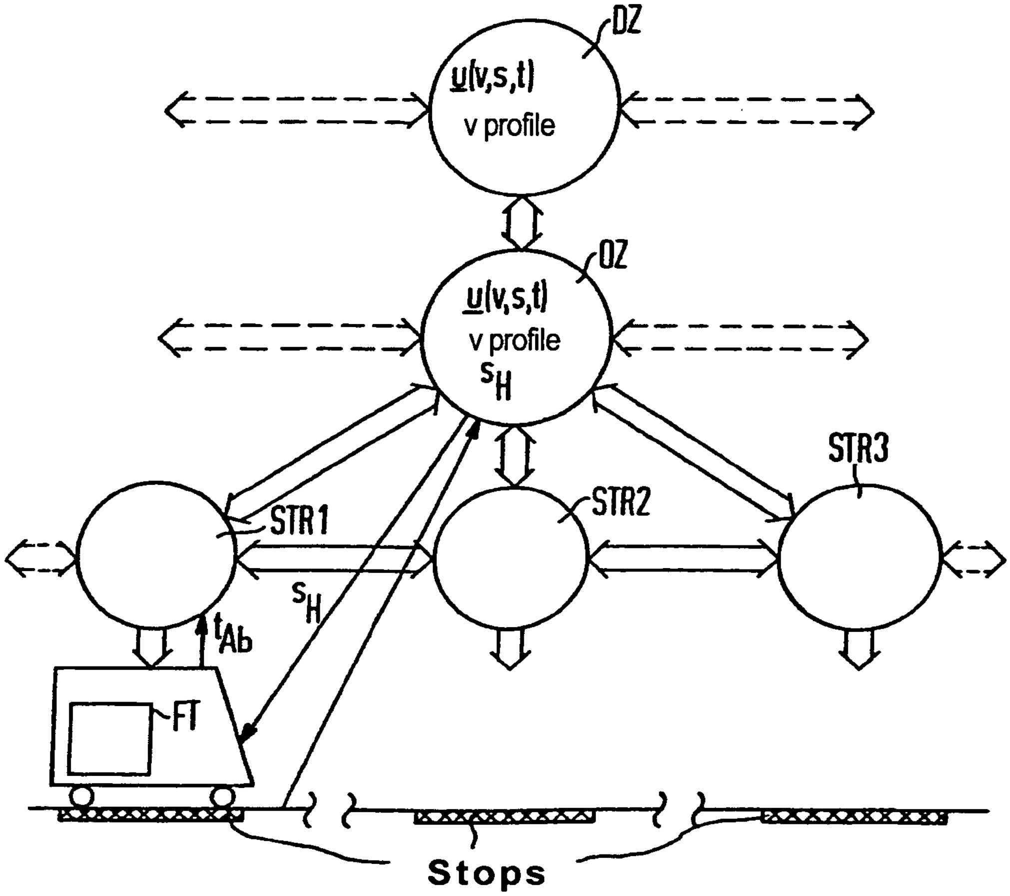

DZ
u(v,s,t)
v profile
OZ
u(v,s,t)
v profile
s_H
STR1
STR2
STR3
s_H
t_{Ab}
FT
Stops

FIG 3

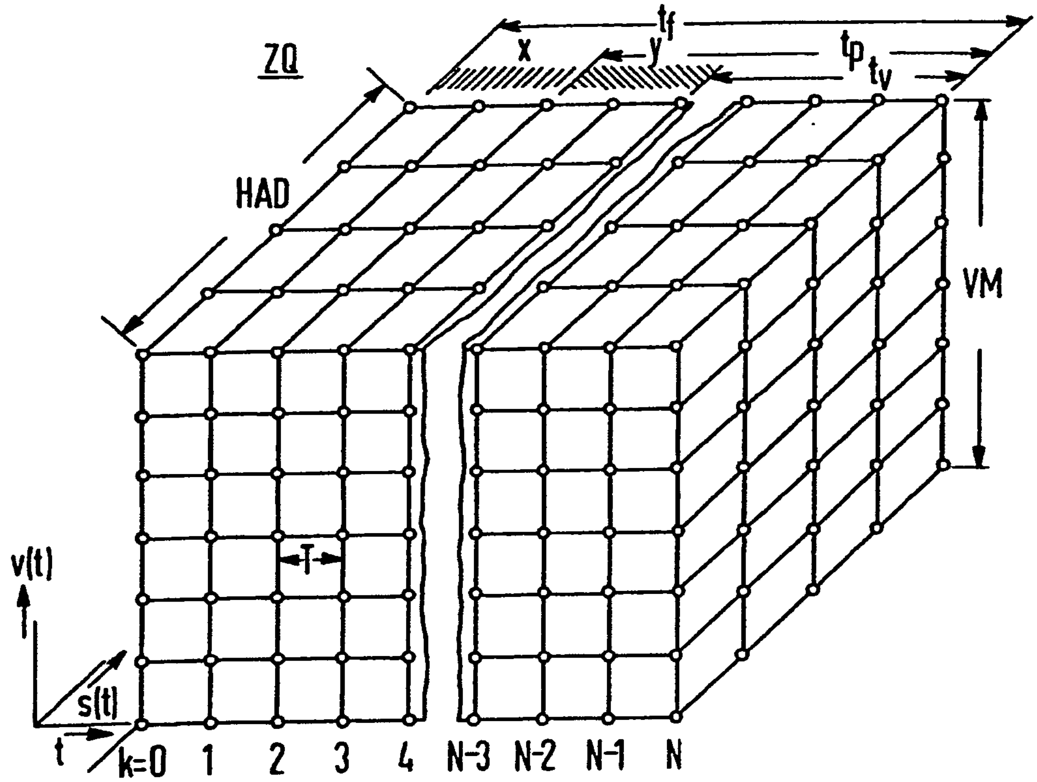


FIG 4

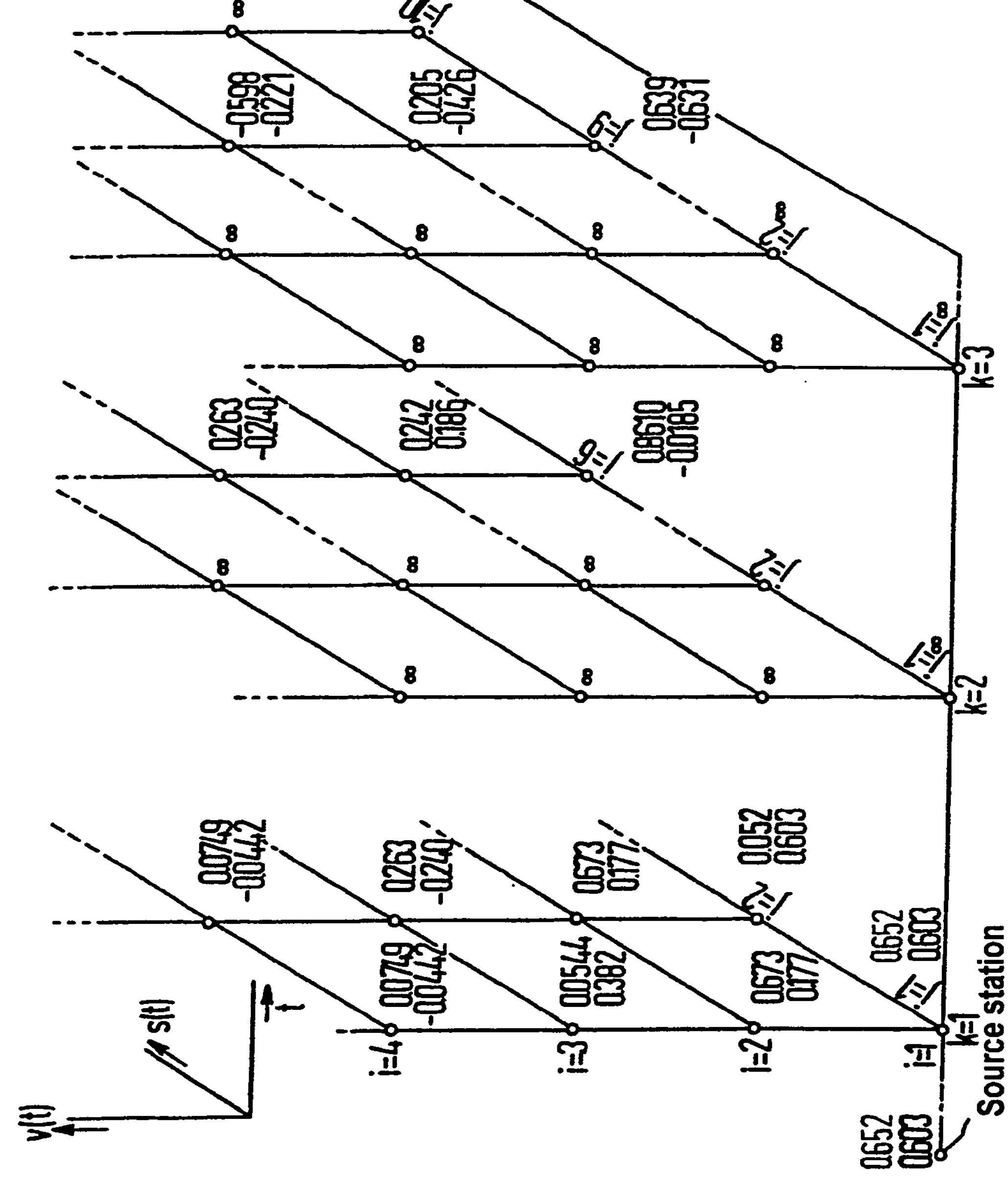

Destination station
Source station
v(t)
s(t)
t
k=1
k=2
k=3
i=1
i=2
i=3
i=4
0.652
0.603
0.0749
-0.0442
0.263
-0.240
0.673
0.177
0.052
0.603
0.0544
0.382
0.242
0.186
0.610
-0.0185
-0.598
-0.221
0.205
-0.426
0.639
-0.631

FIG 5

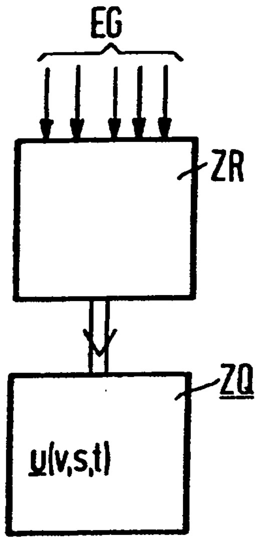


FIG 6

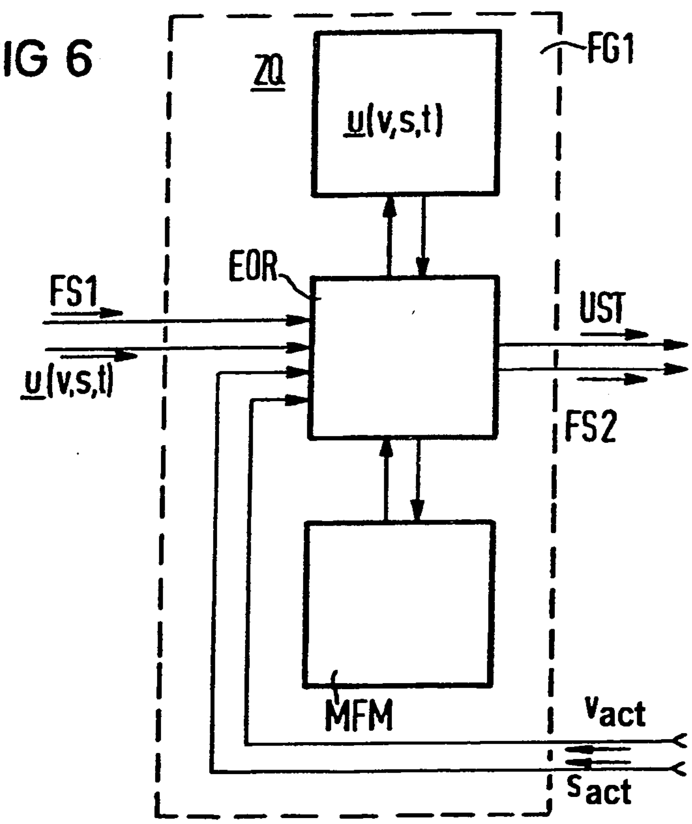
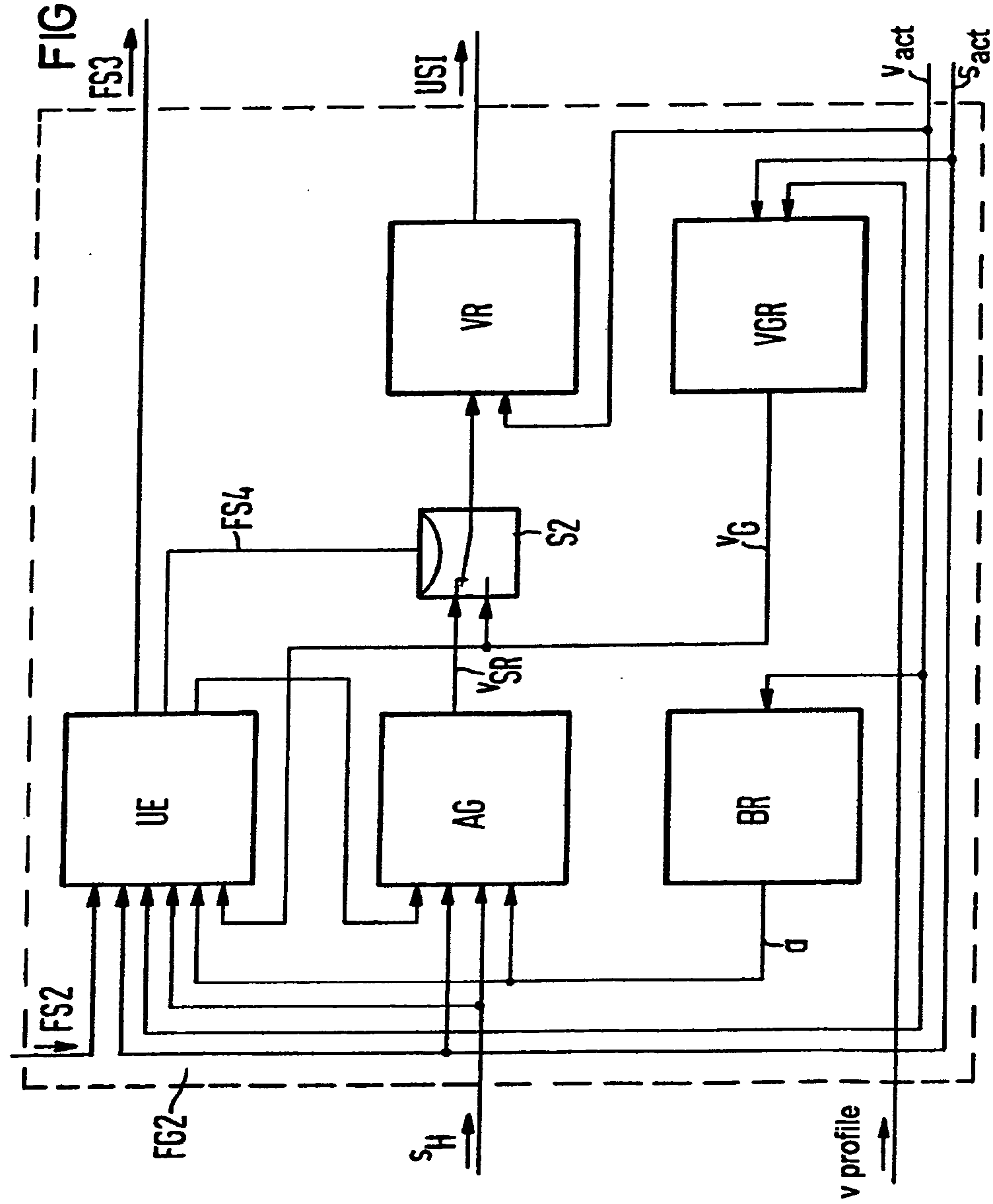


FIG 7



FS3
USI
v act
s act
VR
VGR
FS4
S2
v G
v SR
UE
AG
BR
a
FS2
FG2
s H
v profile